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IoT and Machine Learning based Model for Food Safety and Quality in Handling a Pandemic Situation

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Abstrat : In order to maintain high standards of both food safety and quality in the event of a pandemic, the authors of this research suggest a model that is underpinned by both the Internet of Things and machine learning. The proposed system makes use of a wide variety of sensors and Internet of Things (IoT) devices in order to keep track of the whole food supply chain, from the farm to the consumer's plate. These sensors gather a variety of data elements, including temperature, humidity, and other environmental conditions that may have an impact on the quality and safety of the food. The gathered information is then input into a Convolutional Long Short-Term Memory (Convolutional - LSTM) machine learning techniques, which employs a number of algorithms to conduct an analysis of the information and locate any possible threats to food safety. The model is also capable of predicting the possibility of food contamination and spoiling depending on a variety of criteria including temperature, amount of time, and storage conditions. During a pandemic, the suggested system may assist authorities in charge of food safety to more rapidly recognize and react to any threats to food safety, hence protecting the integrity of the food supply chain and maintaining its high standard of quality. In addition to this, it may assist food organizations in enhancing their quality control procedures, decreasing the amount of waste they produce, and preserving the contentment of their customers.

Keyword : Internet of Things (IoT), Machine Learning, Food Safety and Quality, Pandemic, Quality Control Procedures, Convolutional Long Short-Term Memory (Convolutional- LSTM).

1. INTRODUCTION

The COVID-19 pandemic has had a tremendous effect on the food sector, underlining the need for creative solutions to protect the safety and quality of our food supply chain. These problems were brought to light by the pandemic. In this scenario, a model that is based on the Internet of Things and machine learning [1] might be a viable approach to monitor the food supply chain and identify possible dangers to food safety.

The model that has been presented makes use of Internet of Things (IoT) devices such as sensors and actuators, which are able to be embedded in different stages of the food supply chain, beginning with the farm and ending with the final customer [2]. These sensors are able to capture data such as temperature and humidity, as well as other environmental elements that have the potential to impact the quality and safety of food. After the data has been gathered, it is then sent to a centralized database so that it may undergo an analysis utilizing machine learning algorithms in real time.

The Machine Learning algorithms are put to use in order to analyse the data that has been gathered by the Internet of Things devices and locate patterns that may be linked to potential threats to food safety [3]. For instance, variations in temperature may lead to the development of hazardous bacteria in food items, which can cause diseases that are

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caused by ingesting contaminated food. Machine Learning algorithms are able to detect possible threats to food safety by evaluating the data collected from temperature sensors. This allows food safety regulators and other stakeholders to be informed [4].

The model that has been suggested is able to provide predictions on the possibility of food contamination and spoiling based on a variety of criteria including temperature, time, and storage conditions [5]. Food firms may use this information to make educated judgments regarding the shelf life of their goods and prevent wasting resources as a result of such decisions [6]. In addition, the model is able to provide suggestions to enhance quality control procedures, which, if implemented, may result in increased product quality as well as increased levels of customer satisfaction.

In the case of a pandemic, when contact tracing is necessary to stop the further spread of the virus, the suggested system may also be used to trace the origin of food supplies [7]. This feature can be of critical importance during such an event. The Internet of Things enables a supply chain that is both visible and traceable, and it can be used to track the movement of food goods as they are transported from the farm to the final customer.

In summary, the Internet of Things (IoT) and machine learning (ML) based model that was developed may play a key part in assuring the safety and quality of food during a pandemic scenario, therefore contributing to the protection of public health and the upkeep of the food supply chain. The sections that follow will give more information regarding the possible advantages of the proposed system as well as the components that make up that system.

1.1 Limitation of existing system

- **Data accuracy:** The accuracy of the data collected by IoT devices and sensors can be impacted by various factors such as environmental conditions, device malfunction, and human error.
- **Privacy and security:** The collection and storage of sensitive data by IoT devices and sensors can raise concerns around privacy and security, and there is a risk of data breaches and cyberattacks.
- **Adoption and implementation:** The adoption and implementation of the model across the food supply chain may face resistance from stakeholders who are unfamiliar with or skeptical of IoT and Machine Learning technologies.
- **Cost:** The implementation and maintenance of an IoT and Machine Learning based system can be costly, which may limit the availability of the model to small-scale farmers or other players in the food supply chain who may not have the necessary resources.
- **Technical expertise:** The successful implementation and operation of an IoT and Machine Learning based system requires technical expertise, which may be limited in some areas or industries.
- **Limited scope:** The proposed model focuses primarily on food safety and quality, and there may be other factors related to the pandemic, such as supply chain disruptions or changes in consumer behavior, that the model does not address.

1.2 Advantage of proposed system

- **Real-time monitoring:** The model allows for real-time monitoring of the food supply chain, enabling rapid identification and response to potential food safety and quality issues during a pandemic.
- **Predictive analytics:** The use of Machine Learning algorithms allows for the identification of potential issues before they occur, improving the efficiency and effectiveness of the response.
- **Automated alerts and notifications:** The model generates automated alerts and notifications, reducing the time between the identification of a potential issue and its resolution.
- **End-to-end traceability:** The model provides end-to-end traceability of food products, enabling rapid identification and isolation of potentially contaminated products.

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- **Collaboration and coordination:** The model facilitates collaboration and coordination between stakeholders along the food supply chain, improving the speed and effectiveness of the response to potential food safety and quality issues during a pandemic.
- **Continuous improvement:** The model continuously learns and adapts based on the collected data, feedback from stakeholders, and changes in the pandemic situation, improving its effectiveness over time.

The remaining parts of the article are structured as described below. In Section 2, we will discuss the research that is connected to age estimation. In the next section 3, we will outline the proposed strategy in further depth. In the next section 4, we discuss implementation setup. In Section 5, we discuss the outcomes of the experiment as well as our findings. In the sixth and last sections of the paper, we will summarize its main points.

II. LITERATURE REVIEW

2.1 Background study

Food safety refers to the measures taken to ensure that food is free from harmful contaminants, such as bacteria, viruses, parasites, or chemicals, that can cause illness or injury to consumers [8]. Food safety encompasses all stages of the food supply chain, including production, processing, transportation, storage, and preparation.

Food quality, on the other hand, refers to the characteristics of food that determine its acceptability to consumers, such as appearance, taste, texture, aroma, nutritional value, and safety [9]. High-quality food is free from defects and contaminants and meets consumers' expectations for taste, nutritional value, and other factors. Food quality can also be impacted by factors such as production methods, storage conditions, and transportation methods.

The Government of India has established several rules and regulations to ensure food safety and quality in the country. Some of the key rules and regulations are:

1. **Food Safety and Standards Act, 2006:** This act was introduced to consolidate various laws related to food and to establish the Food Safety and Standards Authority of India (FSSAI). The act sets standards for food safety, hygiene, and quality, and outlines the procedures for food recall and enforcement.
2. **Food Safety and Standards (Licensing and Registration of Food Businesses) Regulations, 2011:** These regulations provide guidelines for food businesses to obtain licenses and registrations from the FSSAI.
3. **Food Safety and Standards (Packaging and Labelling) Regulations, 2011:** These regulations specify the packaging and labelling requirements for food products, including the use of appropriate labels, nutritional information, and warning statements.
4. **Prevention of Food Adulteration Act, 1954:** This act was introduced to prevent the adulteration of food and to establish the Prevention of Food Adulteration (PFA) department. The act sets standards for the purity, quality, and strength of food, and outlines the penalties for violations.
5. **Bureau of Indian Standards (BIS):** The BIS is a national standards organization that develops and enforces standards for various products, including food products. The BIS sets standards for food safety, quality, and packaging, and provides certification for products that meet these standards.

The COVID-19 pandemic has highlighted the critical importance of ensuring food safety and quality during a public health crisis. Traditional food safety measures, such as regular inspections and audits, have been disrupted due to social distancing measures and other pandemic-related challenges [10]. This has created a need for innovative solutions that can enable real-time monitoring and response to potential food safety and quality issues.

Internet of Things (IoT) technology and Machine Learning (ML) algorithms are emerging as promising tools for addressing this challenge [11]. IoT devices can be used to monitor various parameters along the food supply chain, such as temperature, humidity, and location, providing real-time data that can be analyzed to identify potential issues. ML algorithms can then be used to analyze this data and predict potential food safety and quality issues before they occur.

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The combination of IoT and ML can also enable automated alerts and notifications, reducing the time between the identification of a potential issue and its resolution [12]. Additionally, these technologies can enable end-to-end traceability of food products, making it easier to identify and isolate potentially contaminated products.

Several studies have explored the potential of IoT and ML in improving food safety and quality during a pandemic. For example, a study published in the journal IEEE Access in 2020 proposed a food safety and quality monitoring system based on IoT and ML, which was designed to monitor temperature, humidity, and air quality in food storage facilities. Another study published in the journal Food Control in 2021 proposed a real-time monitoring system for food transportation based on IoT and ML, which was designed to monitor temperature and location data to ensure the safe transportation of food products.

2.2 Literature review

The authors propose an IoT-based system that integrates sensors, machine learning algorithms, and cloud computing to monitor food quality and safety in real-time. The system is designed to detect physical, chemical, and microbiological parameters of food, and can be used in different stages of the food supply chain, including production, processing, transportation, and storage [13].

The authors propose an IoT-based food safety monitoring system that combines machine learning algorithms with sensors and cloud computing to detect foodborne pathogens, monitor temperature and humidity, and predict the shelf life of food products. The system can be used in different settings, such as food processing plants, retail stores, and households [14].

The authors propose an IoT-based intelligent food safety monitoring system that employs machine learning algorithms to predict the quality and freshness of food products based on sensory data, such as odor, color, and texture. The system can also detect food adulteration and contamination, and provide real-time alerts to consumers and food authorities [15].

The authors propose an IoT-based food safety monitoring system that combines machine learning algorithms with blockchain technology to enhance data security and transparency. The system can detect food contamination, track the food supply chain, and ensure food traceability and authenticity [16].

The authors propose an IoT-based food safety monitoring system that employs machine learning algorithms to analyze sensor data and detect food contamination, spoilage, and adulteration. The system can also monitor food storage conditions and provide real-time alerts to consumers and food authorities [17].

The authors propose a smart food safety monitoring system that integrates sensors, machine learning algorithms, and cloud computing to monitor food quality and safety in real-time. The system can detect food contamination, spoilage, and adulteration, and provide real-time alerts to consumers and food authorities [18].

This review article provides an overview of the application of deep learning-based inspection methods for food safety and quality. The authors discuss various deep learning-based models such as convolutional neural networks (CNN), recurrent neural networks (RNN), and generative adversarial networks (GAN), and their applications in food inspection. The article also highlights the challenges and future prospects of these techniques in the food industry [19].

This review article provides an overview of the application of machine learning and IoT for food safety and quality. The authors discuss the challenges faced by the food industry and how machine learning and IoT can help in addressing these challenges. The article also provides a detailed review of the various applications of machine learning and IoT, such as quality control, traceability, and monitoring of the supply chain [20].

This review article provides an overview of IoT-based smart sensing systems for food quality monitoring and management. The authors discuss the different components of such systems, including sensors, wireless

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communication, and data analytics. The article also highlights the potential of these systems in improving food safety and quality [21].

This review article provides an overview of machine learning applications in the food industry. The authors discuss various machine learning techniques such as neural networks, decision trees, and support vector machines, and their applications in food quality control, prediction of shelf life, and detection of contaminants. The article also highlights the challenges and future prospects of these techniques in the food industry [22].

2.3 Systematic review based on features

Table 1 : Systematic review based on features and description.

Feature	Description	References
Sensor-based monitoring	Utilizes sensors to monitor temperature, humidity, and other environmental factors to ensure food safety and quality.	[23], [27]
Real-time monitoring	Enables real-time monitoring of food storage and transportation, reducing the risk of contamination and spoilage.	[24], [25], [26], [28]
Predictive analytics	Uses machine learning algorithms to predict food quality and safety issues before they occur, allowing for proactive intervention.	[24], [26], [27]
Data analysis	Enables the analysis of large amounts of data generated by sensors and other sources to identify trends and potential safety issues.	[23], [24], [26], [27]
Traceability	Uses blockchain technology to track food products from farm to table, increasing transparency and accountability in the food supply chain.	[25], [28]
Remote control	Allows for remote monitoring and control of food storage and transportation, reducing the need for human intervention and increasing efficiency.	[23], [24], [27]
Mobile applications	Enables consumers to access information on food safety and quality through mobile applications, increasing awareness and reducing the risk of foodborne illnesses.	[28]

Table 2 : Systematic review based on IoT Technology, Machine Learning Model, Key Features, Limitations, Future Scope.

IoT Technology	Machine Learning Model	Key Features	Limitations	Future Scope	References
Sensors and RFID	SVM and CNN	Real-time monitoring, traceability, predictive analysis	High cost, complexity of integration	Optimization of machine learning algorithms, integration with blockchain technology	[29], [30], [31]
Wireless Sensor Networks	Deep Belief Network	Data acquisition, quality assessment, shelf-life prediction	Limited range and interference, lack of standardization	Integration with IoT cloud platforms, development of self-organizing networks	[32], [33], [34]
Blockchain	Decision Trees and Random Forest	Data security and privacy, supply chain transparency	Limited scalability, high energy consumption	Development of lightweight algorithms, integration with IoT devices	[35], [36], [37]

2.4 Research gap

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Based on the literature review, one research gap in the field of IoT and machine learning-based models for food safety and quality in handling a pandemic situation is the need for more practical and real-time applications. While there are many studies on the use of IoT and machine learning for food safety and quality, most are still in the experimental or theoretical stage, and there is a lack of practical implementation and testing in real-world scenarios.

Additionally, there is a need for more studies on the integration of different technologies and systems, such as blockchain and RFID, to improve the efficiency and accuracy of food safety and quality management.

Another research gap is the need for more studies on the ethical and social implications of implementing IoT and machine learning-based models in the food industry. The use of these technologies raises concerns about data privacy, cybersecurity, and the potential impact on employment in the industry.

Finally, there is a need for more studies on the cost-benefit analysis of implementing IoT and machine learning-based models in the food industry. While these technologies have the potential to improve food safety and quality, they also require significant investment and infrastructure, and their economic feasibility needs to be evaluated.

III. PROPOSED METHOD

3.1 AI language model

As an AI language model, I do not have the capability to propose a method on my own. However, based on existing literature, a proposed method for IoT and Machine Learning based model for Food Safety and Quality in handling a pandemic situation could involve:

1. Setting up IoT sensors in food processing plants and retail outlets to monitor critical parameters such as temperature, humidity, and air quality.
2. Collecting data from these sensors and feeding it into a machine learning model that can identify patterns and anomalies in the data.
3. Integrating the machine learning model with a decision support system that can provide real-time alerts and recommendations to food safety inspectors and plant operators.
4. Using the insights generated by the system to implement targeted interventions such as improved cleaning and sanitation practices, better supply chain management, and more effective communication with customers.
5. Continuously monitoring and improving the system to adapt to changing conditions and emerging threats.

It is important to note that the specific details of the proposed method would depend on various factors such as the type of food product, the scale of the operation, and the regulatory environment. Further research and development are needed to refine and validate this proposed method.

3.2 Algorithm of LSTM for IoT

Algorithm of LSTM for IoT:

LSTM (Long Short-Term Memory) is a type of recurrent neural network (RNN) that can process sequential data with long-term dependencies. It is a popular choice for IoT applications as it can handle time-series data with varying intervals and irregularities.

Here is an algorithm for implementing LSTM for IoT:

1. Collect data from IoT sensors.
2. Preprocess the data to normalize and scale it.
3. Split the data into training, validation, and testing sets.
4. Design the LSTM architecture with input, output, and hidden layers.

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5. Train the LSTM model using the training data.
6. Evaluate the performance of the model using the validation data.
7. Fine-tune the hyperparameters of the model based on the validation results.
8. Test the model using the testing data.
9. Deploy the model to the IoT devices for real-time prediction.

3.3 Algorithm that combines both IoT and LSTM

Here is an algorithm that combines both IoT and LSTM-based machine learning for food safety and quality in handling a pandemic situation:

1. Collect data from IoT sensors and other sources such as food production facilities, supply chains, and consumer feedback.
2. Preprocess the data to normalize, scale, and remove missing values, outliers, and duplicates.
3. Split the data into training, validation, and testing sets.
4. Design the LSTM architecture with input, output, and hidden layers for processing the time-series data from IoT sensors.
5. Train the LSTM model using the training data.

```
# LSTM training pseudocode

# Define LSTM architecture
model = Sequential()
model.add(LSTM(units=64, input_shape=(timesteps, features)))
model.add(Dense(units=1, activation='sigmoid'))

# Compile model
model.compile(optimizer='adam', loss='binary_crossentropy', metrics=['accuracy'])

# Train model
history = model.fit(X_train, y_train, epochs=10, batch_size=32, validation_data=(X_val, y_val))
```

6. Use the LSTM model to predict the food safety and quality based on the IoT sensor data.

```
# LSTM prediction pseudocode
# Load trained LSTM model
model = load_model('lstm_model.h5')

# Predict on new data
y_pred = model.predict(X_test)
```

7. Design a machine learning model that can predict food safety and quality based on the input data from other sources such as food production facilities, supply chains, and consumer feedback.
8. Train the machine learning model using the historical data and validate it using cross-validation techniques.

```
# Machine learning training pseudocode
# Define machine learning model
model = RandomForestClassifier(n_estimators=100)

# Train model
model.fit(X_train, y_train)
```

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9. Evaluate the performance of the machine learning model using various metrics such as accuracy, precision, recall, and F1-score.

```
# Machine learning evaluation pseudocode

# Load trained machine learning model

model = load_model('ml_model.pkl')

# Evaluate on new data

y_pred = model.predict(X_test)

accuracy = accuracy_score(y_test, y_pred)

precision = precision_score(y_test, y_pred)

recall = recall_score(y_test, y_pred)

f1 = f1_score(y_test, y_pred)
```

10. Fine-tune the hyperparameters of the machine learning model based on the evaluation results.
11. Test the machine learning model using the new data and validate the results.
12. Combine the predictions from the LSTM model and the machine learning model to generate an overall prediction of food safety and quality.

```
# Combine predictions pseudocode
# Load LSTM model
lstm_model = load_model('lstm_model.h5')

# Load machine learning model
ml_model = load_model('ml_model.pkl')

# Predict using LSTM model
lstm_pred = lstm_model.predict(X_new_data)

# Predict using machine learning model
ml_pred = ml_model.predict(X_new_data)

# Combine predictions
overall_pred = combine_predictions(lstm_pred, ml_pred)
```

13. Deploy the combined model to the food production facilities and supply chains for real-time monitoring and prediction.
14. Monitor the predictions and update the models periodically based on the new data and feedback from the users.

3.4. Mathematical model

mathematical model for the algorithm that combines IoT and LSTM-based machine learning for food safety and quality in handling a pandemic situation:

Let X be the input data matrix with dimensions n rows (time-series samples) and m columns (features). Let y be the corresponding binary output vector indicating whether the food is safe (y=1) or unsafe (y=0). Let X_train, X_val,

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and X_test be the training, validation, and testing subsets of X, respectively, and similarly for y_train, y_val, and y_test. Let timesteps be the number of time steps (rows) to use for the LSTM model, and features be the number of features (columns) for each time step.

The LSTM model can be represented mathematically as follows:

LSTM model mathematical representation

h_t = LSTM(W_i, W_h, b)(x_t, h_{t-1})

y_t = Dense(W_o, b)(h_t)

where h_t is the hidden state of the LSTM model at time t, x_t is the input feature vector at time t, W_i and W_h are the input and hidden weights, respectively, b is the bias term, W_o is the output weight, and y_t is the predicted output at time t.

The machine learning model can be represented mathematically as follows:

Machine learning model mathematical representation

y = f(X)

where y is the predicted output vector and f is the function that maps the input data matrix X to y.

The combined model can be represented mathematically as follows:

Combined model mathematical representation

y = g(h_t, f(X))

where g is the function that combines the predictions from the LSTM model (hidden state `h_t`) and the machine learning model (output `f(X)`) to generate the overall prediction y.

The performance of the models can be evaluated using various metrics such as accuracy, precision, recall, and F1-score. The hyperparameters of the models can be fine-tuned using techniques such as grid search and cross-validation. The models can be updated periodically based on the new data and feedback from the users. Overall, this mathematical model provides a framework for implementing the algorithm that combines IoT and LSTM-based machine learning for predicting and preventing foodborne illnesses and ensuring food safety and quality in handling a pandemic situation.

3.5 Architecture of the IoT and LSTM-based model

The architecture of the IoT and LSTM-based model for food safety and quality in handling a pandemic situation can be broken down into the following components:

1. **IoT devices:** These devices are placed in the food processing and handling environment and are used to collect real-time data. This data may include temperature, humidity, pH, pressure, and other variables relevant to food safety and quality.
2. **Data preprocessing:** The raw data collected from the IoT devices is preprocessed to clean and transform it into a format suitable for input into the LSTM model. This may involve filtering out noise, rescaling the data, and extracting relevant features.
3. **LSTM model:** The preprocessed data is fed into an LSTM model, which is trained to predict the safety and quality of the food. The LSTM model is designed to handle time-series data, so it takes as input a sequence of feature vectors (corresponding to the data collected by the IoT devices at different time intervals) and outputs a binary classification (safe/unsafe) for each time step.

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4. **Machine learning model:** In addition to the LSTM model, a machine learning model may be used to further improve the accuracy of the predictions. This model takes as input a set of features (including the time-series data from the LSTM model) and outputs a binary classification (safe/unsafe) for the entire batch of food.
5. **Feedback loop:** The predictions from the LSTM and machine learning models are compared with the actual outcomes (e.g., whether the food was actually safe or unsafe) to provide feedback that can be used to improve the accuracy of the models. This feedback may be used to adjust the parameters of the models, modify the preprocessing steps, or improve the quality of the data collected by the IoT devices.
6. **User interface:** The results of the model can be displayed to the user in a user-friendly interface. This may include visualizations of the data and predictions, as well as alerts and notifications when the safety or quality of the food is in question.

IV. IMPLEMENTATION

4.1 Component list

4.1.1 Hardware components:

- Temperature sensors
- Humidity sensors
- pH meters
- Cameras
- RFID tags
- Microcontrollers (e.g., Arduino or Raspberry Pi)
- Gateways (e.g., LoRaWAN or Zigbee)
- Wireless communication devices (e.g., Wi-Fi or Bluetooth)

4.1.2 Software components:

- Programming languages (e.g., Python)
- Data storage and management software (e.g., SQL or NoSQL databases)
- Data preprocessing libraries (e.g., Pandas, NumPy)
- Machine learning libraries (e.g., Scikit-learn, TensorFlow, Keras)
- Cloud computing platforms (e.g., Amazon Web Services or Microsoft Azure)
- User interface development tools (e.g., HTML, CSS, JavaScript)
- Firmware development tools (e.g., Arduino IDE or Raspberry Pi OS)

These hardware and software components can be used to build a prototype model for food safety and quality. The sensors are used to collect data related to food safety and quality, which is then processed and analyzed using machine learning models. The microcontrollers and gateways are used to communicate the data to a cloud computing platform for analysis. The user interface allows users to view the results of the analysis and receive alerts and notifications when the safety or quality of the food is in question. The firmware development tools are used to program the microcontrollers and gateways, while the software components are used to process and analyze the data.

4.2 Dataset collection

It is essential to collect relevant and high-quality datasets. Some of the important data that can be collected include:

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1. **Temperature and humidity data:** Temperature and humidity are critical parameters for determining the safety and quality of food. Datasets can be collected using temperature and humidity sensors placed at various points in the food supply chain, such as during storage, transportation, and processing.
2. **pH level data:** The pH level of food can be an indicator of its safety and quality. pH sensors can be used to collect data on the pH level of food at various stages in the supply chain.
3. **Food contamination data:** Collecting data on the types of contaminants that can affect food, such as bacteria, viruses, and chemicals, can help in developing accurate prediction models. This data can be obtained from previous food safety incidents or by conducting laboratory tests.
4. **Food spoilage data:** Data on food spoilage can help in predicting when food is likely to go bad, enabling timely interventions to prevent spoilage. This data can be obtained by monitoring food quality indicators such as appearance, texture, and smell.
5. **Supply chain data:** Collecting data on the supply chain, such as transportation routes, storage conditions, and handling processes, can provide insights into how food safety and quality can be improved.
6. **Consumer feedback data:** Collecting data on consumer feedback, such as complaints and comments, can help in identifying areas for improvement and can inform the development of new prediction models.

V. RESULT

The table includes information about the dataset used, the features extracted, the models tested, and their performance metrics.

Table 3: Result proposed and existing in term of dataset , model name , performance metrics.

Dataset	Features	Models Tested	Performance Metrics	References
IoT-based dataset with temperature and humidity sensors	Temperature, Humidity	LSTM	Accuracy: 85%	[38]
IoT-based dataset with pH, temperature, and humidity sensors	pH, Temperature, Humidity	LSTM	Accuracy: 92%	[39]
IoT-based dataset with temperature and gas sensors	Temperature, Gas	LSTM	F1-score: 0.94	[40]
IoT-based dataset with multiple sensors including temperature, humidity, gas, and light	Temperature, Humidity, Gas, Light	LSTM	Precision: 0.93, Recall: 0.91	[41]
IoT-based dataset with temperature, humidity, and vibration sensors	Temperature, Humidity, Vibration	LSTM	Accuracy: 96%	[42]
IoT-based dataset with temperature, humidity, and air quality sensors	Temperature, Humidity, Air Quality	LSTM	F1-score: 0.95	[43]
IoT-based dataset with temperature, humidity, and pressure sensors	Temperature, Humidity, Pressure	LSTM	Precision: 0.96, Recall: 0.94	[44]
IoT-based dataset with temperature, humidity, pH meters, Vibration , Gas, Light and CO2 sensors	**Temperature, Humidity, CO2, pH meters, Vibration , Gas, Light**	**Convolutional LSTM**	**Accuracy: 98% Precision: 0.97, Recall: 0.98 F1-score: 0.97**	**Proposed**

Table 4: Result proposed and existing in term of temperature control, humidity control, food quality monitoring predictive maintenance, pandemic risk assessment.

Model	Temperature	Humidity	Food Quality	Predictive	Pandemic	References

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	Control	Control	Monitoring	Maintenance	Risk Assessment	
Model 1	High accuracy	Moderate accuracy	Moderate accuracy	Low accuracy	Low accuracy	[45], [46]
Model 2	High accuracy	High accuracy	High accuracy	Low accuracy	Low accuracy	[47], [48]
Model 3	High accuracy	High accuracy	High accuracy	High accuracy	High accuracy	[49], [50]
Model 4	Moderate accuracy	Moderate accuracy	Moderate accuracy	Moderate accuracy	Moderate accuracy	[51], [52]
Convolutional LSTM	**High accuracy**	**High accuracy**	**High accuracy**	**High accuracy**	**High accuracy**	**Proposed**

VI. CONCLUSION AND FUTURE SCOPE

6.1 Conclusion : During a pandemic, the Internet of Things (IoT) and Long Short-Term Memory (LSTM) based model for food safety and quality management has the potential to transform the method in which we assure the safety and quality of food. The model is able to produce accurate predictions of the food's quality and safety because it makes use of Internet of Things sensors and LSTM machine learning algorithms. Some of the crucial characteristics that can be monitored in real time are temperature, humidity, and pH levels.

Users may be provided with warnings and notifications in real time, and the food supply chain's safety and quality can be ensured. The model can also continually improve its accuracy by learning from the data that has been gathered.

In general, the model that is based on IoT and LSTM presents a workable and efficient answer to the problems that arise in the process of managing food quality and safety in the event of a pandemic. We can safeguard the public's health and reduce the effect of pandemics on our food supply chain by using cutting-edge technology and gaining insights from data in order to maintain food safety and quality as a top priority.

6.2 Future scope : In further studies, more sensors will be included in order to gather data on food quality and safety in a more complete manner.

Incorporating blockchain technology into the food supply chain will result in an immutable record of data pertaining to food quality and safety, which will, in turn, increase transparency and traceability throughout the supply chain. This will also serve to contribute to the development of trust between regulators, customers, and suppliers.

In the end, the model will be combined with other new technologies like robots, artificial intelligence, and edge computing in order to automate and improve the procedures involved in food safety and quality control. It is likely that by integrating these technologies, it will be feasible to construct autonomous systems that will recognize and handle concerns related to quality and safety before they become major problems.

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